THE USE OF LANDSAT DATA TO STUDY MESOSCALE CLOUD FEATURES

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16. Abstract

The objective of this study is the use of LANDSAT data to investigate cumulus cloud banding and the processes which cause it, as well as to correlate meteorological conditions with other mesoscale cloud situations observed by LANDSAT. Analysis of a complex cloud banding case over the Adirondacks on 20 July 1974 gave evidence that processes other than those recognized by the Rayleigh-Kuettner theory are capable of giving rise to cloud bands. Other situations studied verified that elementary wave theory is useful under proper conditions.

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Preface

The purpose of this investigation is the use of LANDSAT data to study cumulus cloud banding and other mesoscale cloud features. The specific objectives are two: to study cumulus cloud banding and determine the physical processes which cause it, and to study the relationships between meteorological conditions and other mesoscale cloud features observed by LANDSAT satellites. These cloud features may include heat island effects caused by urban areas, severe weather situations, tropical cloudiness, high latitude clouds caused by heating from below, transverse waves in cirrus and middle-level clouds, and vortices in stratus cloud fields.

During the third quarter of this study, 43 LANDSAT-1 photographs were obtained from NOAA-NESS showing several cases of cloud banding, wave clouds and severe local storm stituations. Thus, the data set now contains a number of examples of the mesoscale features under investigation. A survey of 1975 LANDSAT photographs is planned for early in the next quarter to identify any additional cases of interest and complete the data acquisition.

Analysis of the cumulus cloud banding cases continued with emphasis placed upon the relationships among the three dimensions of cloud bands and their organization over varying terrain. A more detailed study of the 20 July 1974 cloud banding case over the Adirondacks in New York indicates that mixed modes of cloud organization may occur. In this case, more or less uniform heating over high terrain was manifested by Rayleigh - Kuettner cloud streets. However, forced lifting of the air over isolated mountain peaks, possibly aided by surface heating, produced mechanically induced waves which combined with the moist unstable air to generate cumulus clouds. The final result was a number of single widely spaced cloud streets without any apparent interaction with their environment and a number of irregularly shaped disorganized cloud patterns associated with the irregular topography. Study of the cumulus cloud banding will now emphasize not only the Rayleigh - Kuettner situations but also the identification and explanation of these hybrid cloud patterns.

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1. Introduction

1.1 Purpose and Objectives

The purpose of this investigation is the use of LANDSAT data to study cumulus cloud banding and other mesoscale cloud features. Specifically, this project has two objectives: to study cumulus cloud banding and the physical processes which cause it, and to correlate meteorological conditions with other mesoscale cloud situations observed by LANDSAT. In particular, this study will derive cloud banding parameters from satellite photographs and relate these parameters to the appropriate meteorological and topographic conditions. The results of this analysis will then be compared to the results predicted by theories of shear instability in the Ekman boundary layer.

Because of the areal coverage and detailed spatial resolution provided by the LANDSAT 1 and 2, the satellite photographs are ideal in studying mesoscale cloud conditions. The results of this study should, therefore, permit a better understanding of the formation and characteristics of various mesoscale cloud features. Furthermore, since cumulus cloud banding is closely related to the low level wind field, the results of the study may also lead to the development of new techniques for deriving winds in data sparse areas.

1.2 Summary of Work Performed During the Reporting Period

During this reporting period the work emphasized the data analysis with data acquisition limited to the cases selected and ordered during the previous quarter These cases were received during July and included 14 examples of cumulus cloud banding and eight of wave clouds. Selection and acquisition of appropriate 1975 cases is planned for early in the next quarter.

The analysis of mesoscale features continued with a detailed study of 20 July 1974 cumulus banding case over New York and studies of the wave clouds seen on 13 March 1974 over Maine and 8 May 1974 over Vermont and Western Massachusetts. The 20 July 1974 situation differed from the cumulus banding cases studied previously (17 June 1973 over Massachusetts and 17 January 1974 off the Maine coast) because the extreme irregularity of the underlying topography prevented the smooth, uniform, steady state flow characteristic of Rayleigh-Kuettner type cumulus

banding cases and led to the creation of mechanically induced waves. In the conditionally unstable air, some of these waves produced long isolated cumulus bands, without any apparent interaction with their environment. Elsewhere, irregular cumulus mixed with a few cumulus bands formed over the high terrain.

Detailed measurements of wavelengths, lateral extent and height of the wave clouds were made for the cases of 13 March 1974 and 8 May 1974. These clouds were formed in the lowest two to three kilometers of the atmosphere above the mountainous terrain and were capped by very stable air. Efforts to compare these measurements with the existing highly sophisticated theories of wave cloud phenomena have been hampered somewhat by the lack of precise and appropriately located measurements of parameters such as static stability and the low level wind profile shape. Current efforts are concentrating on selecting the best approach to utilizing the satellite measurements and existing ground truth in studying the wave phenomena, determining lower level winds and identifying areas of changing stability and flow conditions.

2. Progress During the Reporting Period

2.1 Data Collection

During this period forty-three cases of mesoscale cloud features were received from NOAA-NESS. These cases were ordered during the last reporting period and the cloud situations they represent were itemized in the second quarterly report. It is felt that the total data set now available at ERT is probably sufficient for analysis but a trip is planned during the next reporting period to review the 1975 LANDSAT imagery. Any cases of interest will be selected and ordered to supplement or replace the cloud features included in the current data base and to complete the data acquisition portion of this study.

2.2 Data Analysis

Study of cumulus cloud banding cases continued into this period with efforts concentrating on the complex case of 20 July 1974 over the the Adirondacks. The imagery showed cloud streets in various alignments which at first appeared to be due simply to flow distortion caused by topography. However, further analysis revealed that the meteorological conditions characteristic of Rayleigh-Kuettner type cloud streets were not present. The low-level flow was not smooth, uniform and steady-state due to the uneven terrain, nor was a curved wind speed profile found for most of the associated radiosondes. Since these conditions represent the basic assumptions upon which Kuettner's theory of cloud street development is based, it was necessary to investigate other causes of the cloud streets.

As the result of this analysis it was found that cloud bands of the Rayleigh-Kuettner type were formed over high elevations north of Utica, New York and over the uniform terrain of western New York and northeastern Pennsylvania. However, over the Adirondacks, forced lifting of the air by the mountains, possibly assisted by surface heating, had produced mechanically induced waves. In the conditionally unstable air overlying this region, these waves produced cumulus clouds in a number of irregularly shaped patterns which became interspersed among the cloud bands. The final result was a number of widely spaced cloud bands without any apparent interaction with the environment and

a number of disorganized cloud patterns from which it was impossible to derive low level wind speeds.

Analysis of wave clouds also progressed during this period. Measurements were made of the wave lengths, cloud heights and lateral extent of wave cloud found over New England on 13 March 1974 and 8 May 1974. Preliminary analysis indicates that the cloud formations and the surface data show the correlation expected in elementary wave theory. More detailed comparisions of the measurements with wave theories has been hampered by limitations in the ground truth. Thus, efforts are concentrating on selecting the optimum techniques for studying wave phenomena using the satellite photographs and conventional surface observations.

3. Funds Expended

As of 30 September 1975, approximately $16,629.14 had been spent out of the total contract budget.

4. Data Use

LANDSAT-1 imagery ordered late in June arrived during July. No additional imagery was ordered during this reporting period. Thus, the data usage is as follows:

Value of Data Allowed	Value of Data Ordered	Value of Data Received
$1600.00	$196.00	$196.00

5. New Technology

No new technology has been developed during this reporting period.

6. Program for the Next Reporting Period

During the next reporting period, a trip is planned to the NASA-Goddard browse file to select 1975 LANDSAT-1 and LANDSAT-2 imagery. It is hoped that this will complete the data acquisition for this investigation.

Analysis of the cumulus banding cases will continue with particular emphasis on the detection and location of hybrid forms of cloud banding and comparison of such cases with the cloud streets formed by Rayleigh-Kuettner type clouds. Further analysis of the wave clouds will be made especially in regard to quantitatively defining the amount of information that can be derived from satellite photographs.

7. Conclusions

The work performed during this reporting period has identified cases of cumulus banding which contradict existing theories of cloud street formation and represent hybrid cloud conditions. The causes of such cases can be identified and comparison can be made with more organized cloud streets.

8. Recommendations

The work performed during the reporting period has not led to any recommendations for changes in the operation or investigative effort.